

Lifecare Robot: Smart Pill Dispenser for Patients

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Abstract: Healthcare systems face significant challenges in ensuring that patients, especially the elderly, visually impaired, and those with chronic illnesses, take their prescribed medications correctly and on time. Forgetfulness, complex dosage schedules, and dependence on caregivers often result in missed doses, medication errors, or overdosing, leading to serious health risks. To address these issues, the proposed paper focuses on the design and development of a Lifecare Robot that combines electronic control, mechanical dispensing, mobility, and monitoring features to provide an efficient and user-friendly solution. The system uses a microcontroller to dispense medicines stored in separate compartments in precise dosages according to a preprogrammed schedule. Sensors detect pill movement, while alerts, alarms, and an LCD display notify patients and enable interaction. Optional voice assistance supports users with visual or reading difficulties. The robot moves autonomously on a wheeled platform to deliver medicine directly to the patient. A video module monitors and records the medication intake process, providing visual confirmation that the patient has received and consumed the medicine. This data can be shared with caregivers and medical professionals through IoT connectivity. Safety features, such as restricted access and fault detection, prevent misuse. By automating storage, dispensing, delivery, and monitoring, the system reduces human error, eases caregiver burden, and enhances patient safety, independence, and overall quality of life.

Keywords: Lifecare Robot, Healthcare Automation, Raspberry Pi, RFID Technology, Smart Medicine Dispenser.

1 INTRODUCTION

Healthcare systems across the world are undergoing rapid transformation due to the increasing elderly population, rising prevalence of chronic diseases, and growing demand for continuous patient monitoring outside hospital environments. Medication adherence remains a major challenge in healthcare management, particularly among elderly patients, visually impaired individuals, and patients requiring long-term treatment support. Smart healthcare devices are increasingly being adopted to assist patients in managing daily medical routines, improving treatment effectiveness, and reducing dependency on caregivers [1]. Integrated smart healthcare models are being developed to support older adults through personalized monitoring and automated intervention strategies that enhance medication compliance and patient independence. These intelligent healthcare frameworks combine sensor-based monitoring with digital healthcare platforms to improve treatment outcomes and quality of life [2].

At the same time, assistive medical robots are gaining importance in modern healthcare systems due to their ability to support diagnosis, therapy, rehabilitation, and routine caregiving activities with high precision and reliability [3]. The emergence of Hospital 4.0 and Hospital 5.0 environments has further accelerated the deployment of smart sensors and embedded monitoring technologies that automate healthcare workflows and improve treatment accuracy while reducing manual intervention [4]. Additionally, IoT-based smart infrastructure plays a critical role in enabling connected healthcare environments where patient monitoring devices communicate seamlessly with caregivers and medical professionals for real-time supervision and decision-making support [5]. Remote healthcare monitoring technologies integrated within smart home environments are also improving clinician readiness and acceptance of automated healthcare assistance platforms by enabling continuous observation without increasing workload on caregivers [6].

Blockchain-enabled smart hospital architectures are improving the security and interoperability of healthcare data exchange, supporting reliable communication between patients and healthcare providers in connected medical ecosystems [7]. Smart medication management systems have demonstrated significant effectiveness in supporting elderly patients in maintaining proper drug regimens through automated reminders and monitoring features, thereby reducing medication errors and improving treatment adherence [8].

Early developments, such as the M3DITRACK3R mobile medicine dispensing robot, demonstrated the feasibility of robotic medication delivery systems designed specifically for senior citizens requiring assisted healthcare services [9]. Recent advances in digital twin technologies are enabling predictive healthcare monitoring systems capable of replicating patient conditions virtually for improved treatment planning and personalized care delivery [10]. Similarly, digital pill technologies and intelligent monitoring platforms are improving medication tracking accuracy and patient engagement in automated healthcare environments [11].

However, despite these advancements, implementing IoT-based healthcare solutions in developing and rural regions still faces challenges related to affordability, accessibility, and infrastructure limitations [12]. To address these challenges, this paper proposes a Lifecare Robot, an intelligent smart pill dispensing robotic system designed to automate medicine delivery and monitoring using Raspberry Pi-based embedded control, RFID-based authentication, obstacle detection sensors, camera-assisted verification, and IoT-enabled caregiver notification. The proposed system aims to improve medication adherence, reduce caregiver workload, and enhance patient safety through an integrated assistive healthcare automation platform.

2 RELATED WORK

Recent developments in smart healthcare technologies have encouraged researchers to design intelligent medication dispensing platforms capable of improving treatment adherence and patient monitoring efficiency. Smart healthcare devices are increasingly integrated into daily patient support systems to assist individuals in managing medication schedules accurately and independently [1]. Integrated healthcare monitoring frameworks such as the SMART intervention model demonstrate how structured digital healthcare platforms can support older adults through personalized monitoring strategies and automated assistance technologies [2]. In addition, advances in soft medical robotics have enabled the deployment of assistive robotic systems capable of supporting clinical treatment processes and rehabilitation tasks with improved flexibility and safety in healthcare environments [3].

Smart sensor-based hospital infrastructures are also playing an important role in automating treatment scheduling, patient monitoring, and workflow optimization within Hospital 4.0 and Hospital 5.0 environments [4]. Furthermore, IoT-enabled smart city healthcare frameworks support large-scale integration of monitoring devices that enable efficient communication between patients, caregivers, and healthcare professionals through connected digital ecosystems [5]. Remote healthcare monitoring technologies implemented through smart home healthcare systems have demonstrated strong acceptance among clinicians due to their ability to provide continuous supervision without increasing caregiver workload [6]. Similarly, blockchain-supported smart hospital architectures are improving healthcare data security and enabling trusted communication between distributed healthcare systems and monitoring platforms [7]. Smart medication management systems designed for elderly care environments have shown promising results in improving adherence to prescribed medication schedules through automated dispensing and reminder mechanisms [8].

Mobile robotic medication delivery systems such as the M3DITRACK3R robot further demonstrated the effectiveness of autonomous platforms in supporting medicine distribution among senior citizens requiring assisted healthcare services [9]. Recent research in digital twin healthcare environments highlights the role of predictive patient monitoring technologies in improving treatment planning and real-time healthcare supervision [10]. Digital pill monitoring technologies are also improving medication tracking accuracy by enabling automated verification of medicine intake events [11]. However, challenges still exist in implementing IoT-enabled medication monitoring systems in resource-constrained healthcare environments due to infrastructure and accessibility limitations [12]. To overcome these limitations, the proposed Lifecare Robot integrates autonomous navigation, RFID-based patient authentication, camera-based intake verification, and IoT-enabled caregiver notification into a unified assistive healthcare solution that supports both home-based and institutional healthcare environments.

3 PROPOSED METHOD

The proposed Lifecare Robot: Smart Pill Dispenser for Patients is designed as an intelligent assistive healthcare system that automates medicine dispensing, patient authentication, navigation, monitoring, and caregiver notification through an integrated embedded platform. The architecture combines hardware modules such as Raspberry Pi, RFID reader, ultrasonic sensors, motors, camera module, LCD display, and speaker with software-based scheduling logic and IoT-enabled communication services to ensure accurate and reliable medication delivery. The overall system architecture of the proposed Lifecare Robot is illustrated in Fig. 1, which shows the block diagram of the Lifecare Robot smart pill dispenser for patients. As shown in Fig. 1, the Raspberry Pi 4 Model B functions as the central processing unit that coordinates sensor inputs, controls motor operations, executes scheduling logic, and manages communication between hardware components and remote monitoring platforms. The system begins its operation by loading the predefined medication schedule using software-based time logic. Based on this schedule, the controller continuously monitors whether it is time to dispense medicine.

When the scheduled time arrives, the robot activates the navigation module and moves toward the patient location using motor-driven mobility supported by obstacle detection sensors. The navigation process ensures safe movement within indoor environments by avoiding collisions and dynamically adjusting movement paths.

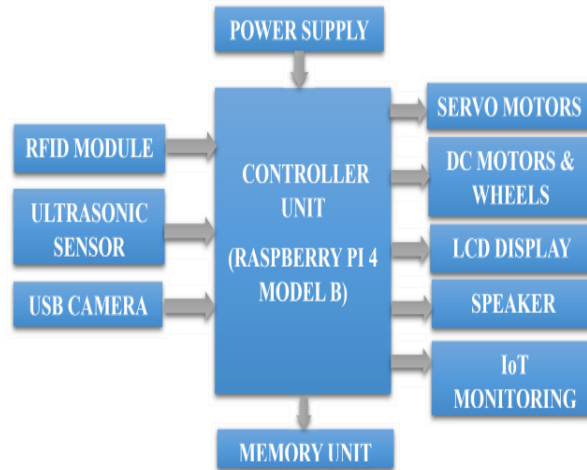


Fig. 1. Block Diagram of the Proposed System

Patient identification and authentication are performed using an RFID reader module integrated into the system. The patient scans their RFID card to verify identity before medicine dispensing. This authentication mechanism prevents unauthorized access and ensures medicines are delivered only to the intended patient. After successful verification, the dispensing mechanism controlled by servo motors releases the correct medicine from the storage compartment. To improve medication adherence and ensure confirmation of medicine intake, the system activates the camera module to record video evidence during dispensing. This recorded information is transmitted to caregivers through email-based notification services using SMTP and MIME protocols. At the same time, the LCD display provides medication information and system status updates, while the speaker generates audio alerts to notify the patient about medicine intake schedules.

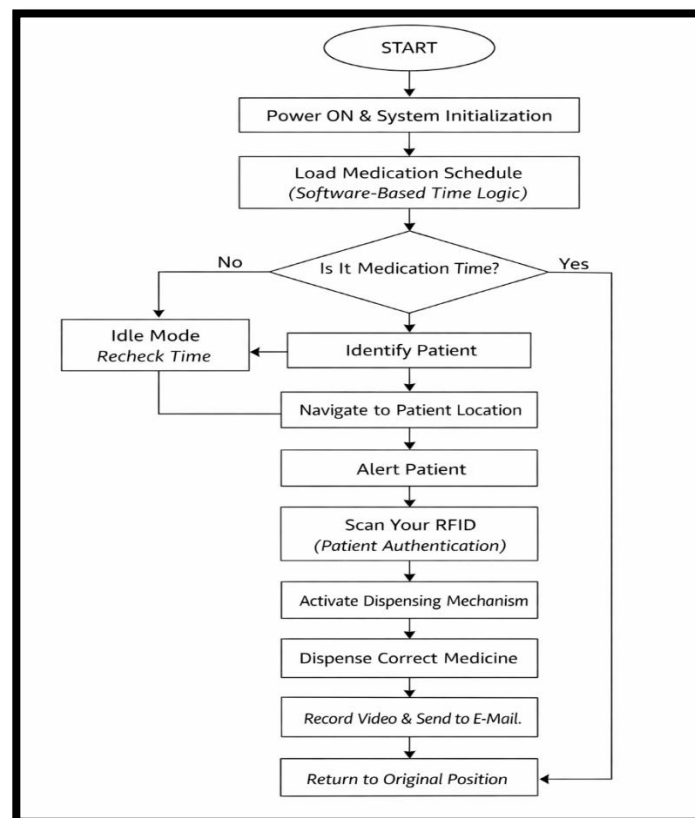


Fig. 2. Working Flow Chart of Lifecare Robot Smart Pill Dispenser

The working sequence of the proposed system is illustrated in Fig. 2, which shows the working flow chart of the Lifecare Robots Smart Pill Dispenser for patients, which describes the step-by-step operational procedure starting from system initialization to medicine delivery and return to the original position. As shown in Fig. 2, the system first performs initialization, loads the medication schedule, verifies whether dispensing time has arrived, identifies the patient through RFID authentication, activates the dispensing mechanism, records medication intake, sends a notification to caregivers, and finally returns to its standby position for the next operation cycle. In addition to automated dispensing, the integration of IoT-based communication enables caregivers and healthcare providers to monitor patient medication activity remotely. This remote monitoring capability improves treatment reliability, reduces caregiver workload, and enhances patient independence. The modular architecture of the proposed system also allows future extensions such as multi-patient support, cloud-based monitoring dashboards, and integration with hospital information systems. Thus, the proposed system architecture ensures safe, reliable, and efficient medicine delivery by combining embedded control, authentication mechanisms, autonomous navigation, monitoring modules, and IoT-enabled healthcare communication into a unified assistive robotic platform.

4 SYSTEM IMPLEMENTATION: HARDWARE AND SOFTWARE COMPONENTS

The implementation of the proposed Lifecare Robot: Smart Pill Dispenser for Patients integrates embedded hardware modules with software-based automation and IoT-enabled communication services to ensure reliable medicine dispensing, patient authentication, navigation, monitoring, and caregiver notification. The schematic representation of the hardware configuration used in the proposed system is illustrated in Fig. 3 which representing the schematic diagram of lifecare robot: smart pill dispenser for patients, it shows the interconnection between the controller, sensors, dispensing unit, mobility module, and communication interfaces.

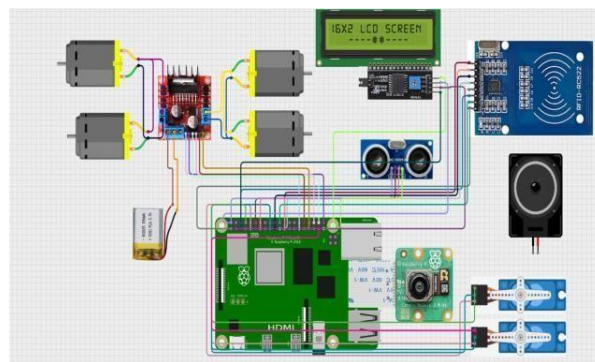


Fig. 8. Schematic diagram of Lifecare Robot: Smart Pill Dispenser for patients

4.1. Hardware Components

The hardware components used in the proposed system are listed below:

1. **Raspberry Pi 4 Model B:** Acts as the central processing unit of the system. It controls sensors, motors, scheduling logic, camera operation, and communication with remote monitoring services.
2. **RFID Reader with RFID Cards/Tags:** Provides secure patient authentication before medicine dispensing, preventing unauthorized access, and ensuring correct medicine delivery.
3. **Servo Motors:** Control the medicine dispensing mechanism with high precision to release medicines according to scheduled timings.
4. **DC Motors with Chassis and Wheels:** Enable robot mobility and allow autonomous navigation toward the patient location inside indoor environments.
5. **Motor Driver Module:** Interfaces the Raspberry Pi with DC motors and controls motor speed and direction safely and efficiently.
6. **Ultrasonic Sensor:** Detects nearby obstacles and supports collision avoidance during robot navigation.
7. **USB Camera Module:** Captures images and records video for monitoring and verification of medicine dispensing activity.
8. **16×2 I2C LCD Display:** Displays medication schedules, alerts, authentication messages, and system status information.
9. **Speaker Module:** Generates audio alerts and reminders for medication timing and system notifications.
10. **Li-Ion Battery:** Provides a portable and reliable power supply for continuous robot operation without external dependency.

4.2. Software Components and Cloud Services

The software tools and communication services used in the proposed system are listed below:

1. **Raspberry Pi OS:** Provides a stable operating environment for managing hardware resources and executing automation tasks.
2. **Python Programming Language:** Used to implement scheduling logic, sensor control, motor control, authentication processes, and communication modules.
3. **GPIO Control Libraries:** Enable interaction between the Raspberry Pi and hardware components such as motors, sensors, an RFID module, and an LCD display.
4. **OpenCV Library:** Supports camera-based monitoring and verification of medicine dispensing operations.
5. **Software-Based Time Scheduling Logic:** Ensures accurate dispensing of medicines according to predefined prescription schedules.
6. **SMTP and MIME Protocols:** Enable automated email notifications containing medication confirmation and recorded monitoring data to caregivers and healthcare professionals.
7. **LCD Display Control Libraries:** Provide efficient control of display messages related to medication schedules and system status.
8. **Thonny IDE:** Used for writing, testing, and debugging Python programs during system development.
9. **SSH Terminal Access:** Allows secure remote access for monitoring, configuration, and maintenance of the Raspberry Pi system.

5 RESULTS AND DISCUSSION

5.1. Hardware Results

The hardware components of the proposed Lifecare Robot: Smart Pill Dispenser for Patients were tested under multiple operating conditions to evaluate navigation performance, dispensing accuracy, authentication reliability, and monitoring capability. The DC motors enabled smooth and stable movement of the robot toward the patient location, while the ultrasonic sensor successfully detected nearby obstacles and ensured safe navigation within indoor environments. The servo motor-based dispensing mechanism accurately delivered the prescribed medicine at scheduled times without spillage or delay. The RFID module reliably authenticates patient identity before medicine release, preventing unauthorized access. In addition, the USB camera module captured clear images and video during medicine dispensing, enabling verification of medication intake. The 16×2 LCD display successfully presented medication schedules and alert messages, while the speaker generated timely audio notifications to assist patients in following prescribed medication routines. Overall, the hardware setup demonstrated stable and reliable performance during continuous system operation.

5.2. Software Results

The software modules effectively coordinated all system-level operations of the proposed robotic platform. The control program developed using Python and GPIO libraries ensured smooth interaction between sensors, motors, authentication modules, and display components. The scheduling logic accurately triggered medicine dispensing according to predefined medication timings. The OpenCV-based monitoring module supported video capture for medicine intake verification, while SMTP and MIME protocols enabled real-time email notifications to caregivers and healthcare providers. The system operated efficiently on Raspberry Pi OS, and development through Thonny IDE and SSH terminal access enabled effective debugging, monitoring, and remote system control. Overall, the software implementation ensured reliable automation, improved medication adherence, and reduced the possibility of human errors in medicine management.

5.3. Discussion

The experimental results demonstrate that the proposed Lifecare Robot effectively integrates intelligent software control with embedded hardware modules to automate medicine management tasks. The automated dispensing mechanism significantly reduces human errors commonly associated with manual medicine administration, thereby improving patient safety, particularly for elderly and bedridden individuals. The dual verification mechanism using RFID authentication and camera-based monitoring ensures secure and reliable medicine delivery to the intended patient. Real-time alerts through the LCD display and speaker improve patient awareness and medication adherence, while automated email notifications enable caregivers to monitor medicine intake remotely. The integration of navigation, authentication, scheduling, and monitoring modules enables the robot to operate autonomously within indoor environments while maintaining high reliability and operational safety.

6 CONCLUSION

The proposed Lifecare Robot: Smart Pill Dispenser for Patients presents an efficient and reliable solution for automated medication management using embedded systems, RFID authentication, camera-based monitoring, and IoT-enabled communication. The system successfully integrates medicine scheduling, patient identification, autonomous navigation, and dispensing mechanisms to ensure accurate and timely delivery of medicines with minimal human intervention. Experimental results demonstrate that the robot operates reliably in indoor environments, providing precise dispensing, obstacle avoidance, and real-time notifications to caregivers through email alerts. The inclusion of audio-visual alerts further improves patient awareness and medication adherence, especially for elderly and physically dependent individuals. By combining hardware automation with intelligent software control, the proposed system reduces caregiver workload and minimizes medication errors. The modular architecture also supports future enhancements such as cloud integration, multi-patient support, and mobile application monitoring, making the system a scalable and practical assistive healthcare solution for modern smart healthcare environments.

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ETHICS STATEMENT

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest related to this study.

LICENSING

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